THE DEVELOPMENT OF TIME-KEEPING IN GREECE AND ROME.

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In my room in the Patent Office there hangs a Connecticut clock of ordinary pattern and quite imperfectly regulated. Its variation of perhaps half a minute in a day, however, gives me no concern, since, being connected by wire with the transmitting clock at the Naval Observatory, it is every day, at noon, set to accurate time. At the moment of 12 o'clock there comes a stroke on a little bell and, simultaneously, the three hands—hour, minute, and second—whether they may have gained or lost during the preceding 24 hours, fly to their vertical position. Immediately after I hear a chorus of factory whistles, sounded in obedience to the same signal, dismissing the workmen to their mid-day meal. At the same moment and controlled by the same impulse the ball, visible on its lofty staff from all the ships in New York harbor, drops, and the seamen compare their chronometers for their coming voyage. The same signal is sent to railway offices and governs the clocks on thousands of miles of track and determines the starting and stopping and speed of their trains. It goes to the cities of the Gulf and of the Pacific as well as to those of the Atlantic coast—noted everywhere as an important element in the safe, speedy, and accurate conduct of commerce; and so the work of the regulating clock of the Observatory, sent out by means which note the minutest fraction of a second of time, is playing its important part in the economy of our century. I cannot follow it out in detail; every one will do so to some extent in his own mind. But if we were to divide human history into eras according to the minuteness with which the passage of time is observed in the ordinary affairs of life we should find ourselves to have arrived, and very lately, in what might be called the era of seconds.

At the opposite extreme is the period when the passage of day and night reveals itself to the dullest intellect. Perhaps no savage people have ever been so dull as not to have noted more than this. We can hardly conceive a state in which the brutal hunter did not take note of the declining sun and observe that the close of the day was approaching. The lengthening of his own shadow was an

always present phenomenon, and men must have observed shadows almost as soon as they became capable of observing anything. But this kind of observation went on for ages without any attempt to subdivide the day, and none but the great natural periods marked off by sunrise and sunset were recognized.

Between this period, marked by the observation of the natural day only, and that in which we live, there have been many steps of progress, the very dates of which may in some cases be quite distinctly observed. We find an era where noon begins to be noted, and the natural day is equally divided by its observation. Then we find an era in which either the entire day or its great natural fractions are again divided into smaller fractions of rather indefinite length, as is now done by some savages and as was done in the earlier history of Greece and Rome. Next to this comes the era in which definite artificial fractions of the day are observed, which may be called the era of hours. It was many centuries after this before men in the ordinary transactions of life counted their time by minutes, but the time when this began is quite distinctly marked.

I would not say that these eras are contemporaneous in all nations, nor could I assert that they correspond closely with any recognized stages in civilization and culture; in fact, the observation of hours of the day does not appear to obtain until civilization is reached, This is true however—men measure most carefully that which they value most, and the value of time is enhanced just in proportion to the multiplicity of the demands upon it which the existing state of society involves. The man who has engagements at the bank, the custom-house, his own warehouse or factory, and in a court-room, and a dozen or more individuals to meet, each of whom, perhaps, has similar pressing engagements, and then must reach an express train at 4.30 in order to dine at 6 fifty miles away, must allot his time with the greatest care and measure it with the utmost minuteness. To the savage, the sun rises and sets and rises again—one day is as another; nothing presses but hunger, and that he endures till fortune brings food. He needs no clock to tell him it is dinner-time, for it is always dinner-time when there is food. When people traveled leisurely by stage coach, walking up the hills to rest the horses, stopping at the wayside inns to dine, and well content at the close of the day if fifty or sixty miles had been covered, seconds of time and even minutes were of little account; but when trains are run on a complex schedule, and for a whole season in advance

it is set down at just what place each train must be at each moment of every day, and the safety of lives and property depends on exact adherence to the prescribed order, then the station clocks must be invariable and synchronous and the conductor's watch true to the second. Civilization is marked at every step of its progress by the multiplication of the varied relations between men, and since the importance of time is enhanced by the same multiplication it may fairly be asked whether the accuracy with which time is observed in ordinary life may not after all afford one of the most perfect indications of the social condition of a people.

The material is not gathered for a full discussion of a question like this, and I shall not occupy myself with it, but as incidental to and suggested by the topic I have chosen some light seems to be thrown on it by the attempt to place in their true correlation facts of history not hitherto brought together. I have proposed to myself only a study of the growth of the common clock, noting the various steps in its development with reference to their period in history and to the social conditions which inspired or demanded them as well as to the state of science and mechanic arts which made their consummation possible. The subject is too large for a single paper, and I have therefore taken for present consideration that part which relates to time-keeping among the ancient peoples from whom we chiefly derive our civilization and to a period of history which, by a sort of coincidence, practically terminates with the beginning of our era. My guide in this inquiry will be the principles in eurematics that inventions always spring from prior inventions or known expedients, and that they come in response to recognized wants. It need not be repeated that these principles find copious illustrations in the progress of every art; but the truth cannot be too strongly enforced that the progress of no art can be intelligently studied or thoroughly comprehended without keeping them in mind.

The few barren and isolated facts that have been preserved to us regarding time-keeping prior to about 600 years ago are not enough in themselves, however carefully collated, to constitute an intelligible or consecutive history. But I need not say that no event is in fact isolated from all others in cause and effect; and if we cannot have direct light we may look to the concurrent events of history for side lights upon our meager facts which will, perhaps, throw them into stronger relief than the direct narration of unphilosoph-

ical historians. Hence, if I shall seem to any one to lean too much upon the synchronisms and sequences of history, it is not that I do not realize the possible fallaciousness of an argument which has no other foundation; but in the progress of inventions such sequences are to be sought for. Invention responds to want, and the want may originate in some crisis or event having no apparent affinity in character with the want it engendered or the invention that sprang to meet it. And these are not mere accidents: they are the natural course of what I venture to call the fixed laws of euremetics. At the same time these laws do not necessarily always call for original invention, since importation of an invention already known elsewhere may equally supply the want, and historical crises are as likely to lead to importation, where it is possible, as to invention. It is with these principles in view, and always looking for such side light as contemporary events can give, that I have attempted to frame the consecutive history of time-keeping, of which this paper is a part.

There are three primitive forms of time-keeping instruments—the sun-dial, the clepsydra or water clock, and the graduated candle. The last plays no part in the evolution of the modern time-keeper, and I shall pass it by without further notice, notwithstanding some interesting historical associations connected with it. But the sun-dial was at the beginning the only time-keeper, and man's ideas, developing into wants, led to its greater perfection till these wants passed far beyond what, with its limitations, it could supply. Its contribution to the present state of the art was not large, mechanically considered, but it was enough to create the demand for something better, and without this contribution the art could not have been. The rude utensil which the Greeks called a clepsydra had no resemblance to the perfected time-piece of this century, but nothing in history is surer than that out of it, by slow accretions, science and art, by turns mistress and handmaid, have produced the masterpiece of both.

This history is, therefore, the history of a human want and of a mechanical structure developed in response to it. But wants grow, and this has grown; and in tracing it we do not find it always in the same likeness. Sometimes the want of the moment is satisfied, and then it appears in a novel and unexpected form, altered in its whole complexion by that which has just appeased it. And as we recognize this Protean character, we need not suppose that the

Babylonian astrologer who made some improvement in a sun-dial had a single idea or purpose in common with those of a railway manager who last week connected his regulator by wire with the Observatory. We trace our want in the development of institutions, in the creation of new demands upon time, in the growing complexity of human relations, in political crises, and we may determine its character or intensity by the means used to supply it and the generality of their adoption. The story of the growth of the instrument is inseparable from that of the growth of civilization.

Writers on the history of the clock (and they are not few) have generally begun by a reference to the sun-dial as a Babylonian or Chaldean invention. We can trace it no further, and have no means of determining when the invention was made. We learn from the Old Testament Scriptures that it was known at Jerusalem as early as seven centuries before our era, and the manner of its mention indicates that in that city it was a novelty. King Ahaz, by whose name this dial is called, had introduced other novelties into his capital on his return from Damascus, whither he had gone to make his submission to Tiglath-Pileser II, King of Assyria; and it is not unreasonable to suppose that the dial had the same origin. However this may be, it was a graduated instrument, having degree marks of some kind which showed the daily course of the sun. We may infer that it was at least of a Babylonian pattern, and it points to a remote period when a graduated dial indicating the time of day by a shadow passing over it was known to Oriental peoples.

Presumably it was their invention. The suggestion that they derived it from Egypt is a guess only, based on the supposed earlier growth of Egyptian science. To such a guess might be opposed the fact that in all the Egyptian monuments yet explored there is no hint of such an instrument.

The Assyrian monuments are equally silent; and the same speculation which attempts to account for the absence of all representation of a sun-dial in the sculptures which have revealed to us so much of the domestic life of the Assyrian people applies to Egypt also. We may believe that it was not a device generally known or commonly used. Very likely the knowledge of it was confined to the priests and magi, who were not only ministers of the religion of each country but the masters of its science. This device constituted a part of their mystery and was religiously kept from the public knowledge. In support of this conjecture it may be said

that the Phœnicians, who penetrated every land, dealt in every merchantable commodity, and from their active commercial habits were the very persons who would have found the use of a time-piece most valuable, do not appear to have known of any such instrumentality; but the inner temples of Thebes and Babylon were not open to those hardy mariners, and the exhumations of Cyprus reveal no more to us than those of Nimroud and Memphis.

It is scarcely profitable to grope in the darkness for the origin of the sun-dial; but certain facts are apparent and may be briefly indicated. In Egypt and Assyria observation of the heavenly bodies was a part of the religious cult. The regulation of the calendar belonged to the ministers of religion. For the regulation of the calendar, which of course involved the determination of the length of the year, the recurrence of the solstices must be noted; and these could only be noted by observation of the day when the shadow cast by the sun at noon was at its maximum or minimum. The observation of shadows for the determination of noon led (it could scarcely be avoided) to their further observation during the entire period of the sun above the horizon, and, at last, to marking the surface on which the shadow was cast by permanent lines dividing the day into some kind of regular parts. All this might be done as a matter of scientific observation without conscious need of a time-piece.

The sun-dial took many forms, and more than one of these may have been known to the Babylonians. The art of dialing involved mathematical problems of considerable complexity, and the study of this art very likely contributed to the knowledge of mathematics that the world possessed at that early period. The consideration of these forms is not germane to my present purpose, which is for the moment only to show that long before the appearance of the sun-dial in Greece the instrument had been apparently perfected by the wise men of the East.

Historians have agreed in fixing the period of the introduction of the sun-dial into Greece in the latter part of the sixth century B. C. Herodotus says it was derived from the Babylonians, from whom he also declares the Greeks to have derived the twelve parts (δυώδεκα μέρεα) of the day. Others, however, ascribe its invention to Anaximander, who is said to have set it up in Lacedæmon. It is evident that he need not have invented it, but might have brought it from some country where its use was already known. It is signifi-

cant that Anaximander and Anaximenes (to whom some writers ascribe the honor of the invention), were both fellow citizens and pupils of Thales of Miletus, and that the date of this introduction synchronizes with the extensive and intimate acquaintance between Egypt and Greece, which, commencing in the reign of Psammetichus, reached its culmination under Amasis, the fourth king of that dynasty, and in which the people of Miletus bore the most prominent part. Under this last king, whom they assisted in throwing off the yoke of Assyria, Greeks swarmed in the Egyptian court, filled her armies, manned her fleets. They passed to and fro continually; Greek philosophers pursued their studies in Egyptian schools: and who shall say how many of the secrets of art and science found their way at that time from the land of the Pharaohs to the spirited and versatile people just emerging from barbarism across the Mediterranean? Surely, if under such conditions anything of Egyptian origin or likely to have been in Egyptian possession is found to have made its appearance among the Greeks, we need not speculate as to how it got there.

It does not appear that the sun-dial was introduced to the Greeks in any perfected form. On the contrary, it was at first a mere staff or pillar (γνώμων), destitute of any graduated dial which could indicate the passage of an hour or any definite fraction of a day. The length of the shadow, measured in feet, determined the time for certain regular daily duties, as a shadow six feet long indicated the hour for bathing and one twelve feet long that for supper. More accurate and convenient forms were perhaps known to philosophers; but, if so, they did not come into common use. This simple device was sufficient for the simple habits of the people. The twelve parts of the day of which Herodotus speaks had no meaning to the Athenians, who had no word meaning specifically *an hour;* and as late as the time of Alexander, the old system seems to have been followed. This kind of observation, it may be remarked, was perfectly feasible in the shadow of an Egyptian obelisk, which may partly account for the absence of the instrument from other monuments of that country. As a matter of history, an obelisk at Rome was actually used for a sun-dial in the time of Augustus.

We learn from this history at what period and in what stage of progress the Greeks first had the idea of measuring time. If we associate it with the period of Solon, the Athenian law-giver who died about 570 B. C., we may form some idea of the condition of

the people of Athens from the character of his legislation and the miseries he attempted to mitigate. The Greeks had written language and they had literature—Homer, Hesiod, Sappho. They had a system of weights and measures and a coinage. They were prolific in political ideas. But the period just previous to Solon was marked by the tyranny of the oligarchs, the severity of whose legislation gave the term "Draconian" its significance, by widespread poverty, by slavery, by the decline of agriculture and industry, and by the unceasing war of factions. Athens was emerging from such conditions as these, under the reign of Pisistratus, at the moment when the Milesian philosopher is said to have introduced the sun-dial. We may conceive that the conditions were not favorable to the general adoption of any novelty of this character, but it is noticeable that this period was followed immediately by one of democratic ascendency under the constitution of Cleisthenes, in which the naval power and commercial importance of Athens were vastly augmented, and which continued without interruption until his invincible phalanxes laid all Greece at the feet of Philip of Macedon.

It was during this era of maritime vigor, of commercial prosperity, and of dominating influence at home and abroad, that Athens achieved that splendor in art which has made her a beacon light for all subsequent peoples and ages; and in this period time-keeping in common life had its first development. But the sun-dial is an instrument of limited capacity; however perfected, it was valueless in the hours of night and in the days of cloud and storm that even sunny Greece does not always escape. But, more than this, it was incapable of indoor use; and in the outgrowth of institutions under democratic order and among a litigious and voluble people a new and singular want had arisen demanding some means of checking time which, from its limitations, the sun-dial could not supply. With her other arts, that of oratory had developed in Athens; but every orator was not a Pericles, and whatever may have been the merits or defects of their performances the inordinate length of these was too great a tax on the tribunals. It therefore became necessary to limit and apportion the time of public speakers in the courts, and to do this equitably some practical means of indicating time was necessary. Hence arose the demand for another instrumentality whose origin and history are now to be traced.

It is proper to pause for a moment here to note a distinction between two kinds of instruments used to measure time. A continuous instrument like a clock, which marks off the hours of the day and night as they pass successively away, is what is called in common language a time-keeper; but there is a class of instruments which do not keep the record of continuous time, but are used only for the checking of brief periods; such an instrument is the glass by which the seaman observes his log or the cook boils her eggs. To such instruments, for the want of a better term, I give the name time-checks, to distinguish them from time-keepers. Their use is quite distinct from that of observing the time of day, and yet it is apparent at once that, by careful attendance, as by turning the hour-glass at the moment when its last sand has run out, the time-check may be made to perform the office of a time-keeper. The allusions of ancient writers and of some modern ones to devices of these two classes are sometimes misleading and confusing because this distinction has not been kept in view. It is particularly important in the study of the clepsydra, which is originally a time-check only, while the sun-dial is a true time-keeper.

The clepsydra or water clock, in its simplest form, is traced by historians no further than Greece, about 430 B. C., in the time of Aristophanes, whose familiar references to it show its use for certain purposes to have been common.

I confess I have been far from satisfied with stopping at this half-way house in seeking for the origin of this instrument. I have sought further, and what I have found, if conclusive of nothing, is at least suggestive.

If, taking our lives in our hands, we could step on board a Malay proa we should see floating in a bucket of water a cocoanut shell having a small perforation, through which the water by slow degrees finds its way into the interior. This orifice is so proportioned that the shell will fill and sink in an hour, when the man on watch calls the time and sets it afloat again. This device of a barbarous, unprogressive people, so thoroughly rude in itself, I conceive to be the rudest that search of any length can bring to light. It is in all aspects rudimentary. One can scarcely conceive of anything back of it but the play of children, and, as a starting point for this history, it is much more satisfactory than what is disclosed in the polished ages of Greece. There is nothing in its structure, if we were to consider that only, to prevent it from being a survival

of an age long antecedent to the use of metal. The protolithic age might have originated it if we can conceive that protolithic man could have had use for it.

Leaving our piratical friends, to whom we are so much indebted, and passing to their not remote neighbors in Northern India, we find the rude cocoanut shell developed into a copper bowl. Its operation is the same, but the attendant, who stands by and watches the moment of its sinking, now strikes the hour on the resonant metal. It is easy to see—in fact it would be difficult to doubt—that this has been an improvement on an apparatus like that of the Malay and the natural result of improvements in other arts, eminently that of metal-working. It is more enduring, more perfectly accomplishes its purpose, and is in the precise direction that improvement on the ruder appliance might be expected to pursue.

Passing from Southern Asia to a people geographically remote, I next observe the water clock in use up to this day in China. We find the metal vessel with its minute perforation as before, but it has undergone a radical change in respect to its manner of use. It is now filled and the water flows from it in drops. Obviously enough the flight of time might be indicated by merely observing when the vessel has emptied itself and then refilling it, which, as will presently appear, was exactly the simplest Greek and Roman clepsydra and differs in no mechanical respect from the ordinary sand glass.

But in the days when the Chinese were a progressive people and developed inventions for which Europe had many centuries to wait, this water clock advanced far beyond the crude thing we have been considering. It would seem that the problem was to increase its usefulness by subdividing the unreasonably long intervals required for the complete emptying of the vessel. If this was done by marking graduations on the inside of the vessel and so noting the decline of the level the difference in its rate could not fail quickly to make itself manifest. The solution of this problem, not obvious at first, was found in so arranging the vessel that it should discharge into another, where the indication would be read in the rise of the surface, and contriving to hold the water in the upper vessel at a constant level. This was done by employing a third source, from which there was a constant flow into the first equal to its discharge. As the head in the middle vessel is thus maintained constant, the rise in the lowest is made uniform. Another radical improvement

enhancing the practical utility of the device was the arrangement of a float on the surface of the water in the lowest vessel. Upon this was an indicator or hand which, in its rise, traveled over an adjacent scale, and so gave a time indication visible at a distance.

To show what progress this structure implies in the development of the mechanical clock it is worth while to glance a moment at the essential elements of such an instrument. Reduced to its lowest terms a clock consists of three elements only. These are a motor, or source of power, represented in our clocks by a spring or weight; an escapement, or a means by which the stored power in the motor is let off at a measured rate; and a dial, which is but the means by which the rate at which the power is let off is made visible to the eye. In this Chinese water clock we discover all these elements. Water, acted on by gravity, is a familiar form of motor; the small perforation through which it slowly trickles drop by drop is a true escapement, doing in its place just what our complicated mechanisms are doing in theirs; and, rude as it may appear, it is one which mechanicians of our time are not ready to dispense with. The visual indication is given by the rise of the float, causing the pointer to pass over the scale. Going backward from this Chinese clock we perceive, but less distinctly, the same elements in the Indian and Malay devices, in which the operation is reversed. In these the weight of the vessel, held up by the resistance of the water in which it floats, is the power; the perforation admitting the water by slow degrees is the escapement, and the only indicator is the visible sinking of the vessel itself.

The three devices described correspond in the degree of their perfection with the conditions of art and culture among the peoples to which they belong; and, as these conditions appear to have been unchanged for a long period, we hazard little in assuming that they date from a remote epoch. A description of the Hindoo instrument appears in a Sanscrit work on astronomy in which it is adopted for astronomical observations, and Chinese writers do not hesitate to ascribe the invention to Hwang-ti, who flourished, according to their chronology, more than twenty-five centuries before our era, and its later improvement by the introduction of the float to Duke Chau fourteen centuries later.

In describing these three devices in the order in which I have placed them I do not mean to be understood as intimating that they have followed the same order in respect to the time of their develop-

ment nor that they have been transmitted from one people to another in the same order. I have, for convenience, proceeded from the lowest form to the highest; but it may well be true that the lower was an adaptation from the higher, fitting it for coarser needs, and so being in a certain sense an improvement. Consideration of the lines of commerce might, in fact, lead to the suspicion that the Malay got his notions from the Chinese, since they must for many centuries have sailed the same waters and been in frequent contact.

But we may come further west. Writers on this subject, while attributing to the Chaldeans the invention of the sun-dial, do not generally accredit them with the knowledge of any other instrument for measuring time. But if we may take as an authority Sextus Empiricus, who wrote near the end of the second century of our era, they had, as he tells quite minutely, the same device and used it in their astronomical observations. "They divided," says this author, "the zodiac into twelve equal parts, as they supposed, by allowing water to run out of a small orifice during the whole revolution of a star, and dividing the fluid into twelve equal parts, the time answering for each part being taken for that of the passage of a sign over the horizon." I see no reason for doubting this. In fact the division of the zodiac into twelve signs seems to require a means of measuring the passage of time at night, and this fact and the story just quoted tally with the conclusion that an instrument of the common generic character borne by all the forms I have described was known among widely distinct peoples of Asia before the dawn of European civilization.

Such an invention is not likely to be lost by political changes while supremacy in the exact sciences is maintained. We know that down to the Medo-Persian conquerors of Babylon each successive dominant race adopted, as has often happened in history, the dress, the manners, and the arts of the conquered; and we need not doubt that this instrument was in use in the Persian Empire when its sword first crossed that of the Greeks.

No record exists of the introduction of the clepsydra into Greece. We might infer from the absence of all reference to it by Herodotus that up to the period when his history ends, 478 B. C., it was not known. Fifty or sixty years later, when Aristophanes was writing his comedies, it was absolutely familiar in Athens. The interval named seems short in accounting for so radical a change in the habits of a people as is implied by the general introduction of such an appli-

ance; and yet, if we ask ourselves as to the condition of the electric telegraph or the sewing-machine fifty years ago or of the telephone ten years ago, it need not startle us to conceive that a versatile people like the Greeks were capable of as swift changes in their habits of life as these inventions have induced in ours. That this epoch saw more than one change in Athens, in the aspect of the city, in the habits of the people, and, above all, in their advance in culture and refinement and the arts of peace, we may be sure when we remember that it includes all the years of Pericles's administration. It includes, also, the abandonment by Sparta, always unprogressive, of the leadership of the Greek commonwealths, and with this abandonment the removal of the reactionary influences hitherto a clog to the enterprise and prosperity of Athens and of all Greece.

In the absence of data on this subject it seems not unreasonable to believe that the knowledge of the clepsydra, which was widely spread among Oriental peoples, was introduced into Athens from the East during or at the termination of the second Persian war; and, if we choose to surround its introduction with the halo of romance, it is not hard to conceive that these useful devices of civilization were gathered up among the spoils of Platæa or washed ashore with the wrecks of Salamis. A more commonplace and not less likely conjecture would be that the instrument was already becoming known in the Greek colonies of Asia, and, perhaps, even in Athens herself, through intercourse with the Persians and other Oriental peoples. It came into common use in obedience to the want, not of a time-keeper, which was already supplied, but of a time-check—a want created by the conditions of Athenian society which I have already described and which the only known time-keeper could not satisfy.

If the increasing burden and tediousness of litigation led to the enactment of a statute restricting and apportioning the time of speakers in the courts, and providing this means for its regulation, it is easy to see that the use of such means must become at once familiar. I have found no trace of such enactments, but that strict ordinances existed there is no doubt. We know that the time of speakers was carefully proportioned to the importance of the case; and trials of importance enough to have the time apportioned were known as πρὸς ὕδωρ, while those of trifling importance, in which, perhaps, no lawyer appeared, were known as ἄνευ ὕδατος: two terms which may be freely rendered *wet* and *dry*, the dry case being as it happens most quickly

disposed of. In a case of great moment to the state, involving a charge of faithlessness in an embassy, each party was allowed 10 amphoræ, or about 50 gallons of water. Nothing, however, seems to be known of the actual length of time indicated by this quantity of water. A passage in Aristotle gives some idea of the form of the clepsydra as commonly used; it was a spherical bottle with its minute opening at the bottom and a short neck at the top, into which the water was poured. The running out of the water at the bottom could be stopped by closing this neck. In using the word bottle I do not mean to imply that this clepsydra was of glass. Glass vessels of a suitable size could not be made at that period.

The familiar association of this device with the courts is shown in many ways. Aristophanes throughout his comedies is in the habit of using the word clepsydra as a synonym for court of justice, and in a humorous passage in *The Wasps* the impossibility of conducting a trial without it is quite forcibly set forth, by the introduction, to supply its place, of a vessel intended for less refined purposes. In fact, ὕδωρ became a synonym for time. We find Demosthenes charging his opponent with talking ἐν τῷ ἐμῷ ὕδατι, "*in my water;*" and on another occasion he shows the value he attached to the time allotted to him by turning to the officer, when interrupted, with a peremptory σὺ δὲ ἐπίλαβε τὸ ὕδωρ, "*You there! Stop the water!*"

I shall again have to refer to this use of the clepsydra when I come to the Roman period of this history, and will not follow it further now; nor shall I consider its use as a time-keeper, which, if ever general in Greece, was not until a very late period, belonging, rather, to the Roman chapter also. The story that Plato had a clepsydra which indicated the hours of night is of little moment, although it is frequently taken as indicating some kind of a striking apparatus; but the language of the author who is the only authority for the statement contains no allusion to an audible signal, nor in fact any intelligible allusion except to a larger clepsydra than usual.

In fact, all the improvements by which this instrument was converted into a time-keeper belong to so late a period of Greek history that it is more convenient to consider them further on.

Where Greek colonies were founded and where Greek influence predominated Greek arts and culture flourished also. Under the Ptolemies Alexandria became a second home of art and science not inferior to Athens herself. To a greater or less extent the same must have been true of the great cities which dotted the northern

coast of the Mediterranean, such as Tarentum, Agrigentum, and Syracuse. With kindred people, similar culture and needs, and with unceasing commercial intercourse, there is no reason to doubt that whatever was in common use in the mother cities found its way to them also. It was in Alexandria that in the shape of what is appropriately termed the water clock the clepsydra attained its highest development, in the inventions of Ctesibius, who is placed by some writers in the third century B. C. and by others with more probability in the second. I reserve these inventions also for the latest epoch in this history, to which they seem more properly to belong, and will now pass to Rome.

There is no reason to believe that the Etruscan people, with all their proficiency in certain arts and a vigorous and extensive maritime commerce, possessed any artificial means of indicating time. If they had, it could hardly have failed to come into use among the Romans, whose relations with them for centuries were close, even if generally hostile. But it was not till a late period, long after Etruria had been crushed under the successive assaults of her northern and southern enemies, that any device of this character was known to the people of Rome.

Indeed, the condition of society and of the arts in Rome at that era was not such as to require any reckoning of the time of day beyond the observation of sunrise and sunset. In the twelve tables, which date from the middle of the fifth century B. C., noon also is mentioned. But the facts that history has preserved to us show that the Romans of that time were a thoroughly rude and almost barbarous people. It was not till two centuries later than this, in the year of Rome 485 (268 B. C.), that silver coinage was first struck. Pliny says that barbers were first introduced about the same time, and that till then the Romans had gone unshorn. Cicero says the arts which had reached some degree of perfection in Etruria were even allowed to retrograde. He says the Romans had some knowledge of arithmetic and land surveying, but they could not improve their calendar and were not even in condition to erect a common sun-dial. As to the state of commerce and agriculture we are told that in the fourth century of Rome private enterprise was so inadequate to the provisioning of the city that state commissioners were placed in charge of it.

It would seem that Rome was at that period a capital, populous indeed, but without arts or sciences, without industries, and without

cultivation. War was the only trade and plunder the only source of public or private revenue. For the civil purposes of such a people the natural divisions of time were all that were necessary. They marked the periods for toil and repose and that was enough.

These were a ruder people than those of Athens in the time of Solon; but if they had less of culture they had less of tyranny and less of intestine warfare to contend with at home than had the Greeks, and they were always reaching out, widening their domain, absorbing neighboring peoples, and making each in its turn add to the strength and glory of their capital. Whatever the art and science of the subdued nations could contribute to the prosperity of Rome came by the enforced levy of the conqueror.

The time system of early Rome was, like everything else, of the rudest character. Growing out of their military habits and adapted to them, it divided the day and night each into four watches, the periods of which must have been roughly determined by observation of the courses of the sun and stars. In the city, according to Pliny, noon began to be accurately observed some years after the publication of the law of the twelve tables. The *accensus* watched for the moment when, from the Senate House, he first caught sight of the sun between the Rostra and the Græco-Stasis, when he proclaimed publicly the hour of noon. From the same point he watched the declining sun and proclaimed its disappearance.

Authorities differ as to the date of the introduction of the sun-dial into Rome. Pliny attributes it to the consul L. Papirius Cursor, who set it up at the temple of Quirinus. This has been supposed to be a trophy from the Samnite war, but, as the Samnites were a ruder people even than the Romans, that seems scarcely credible. Varro, as reported by Pliny, gives a clearer story, that the first public sun-dial erected in Rome was fixed upon a column near the Rostra in the time of the first Punic war by the Consul Valerius Messala, and adds that it was brought from the capture of Catina. The date given by Varro, 491 A. U. C., corresponds to 262 B. C., and is about 30 years later than that ascribed by Pliny to the dial of Cursor. As a source for this instrument Sicily, with her Greek arts and refinements, is much more probable than the rude Samnite people, and, with real appreciation of Pliny's frankness, we may accept the story he quotes from Varro in preference to his own.

What were the social conditions in Rome at this period, the middle of the third century before our era? It needs scarely more

than a glance at a chronological table to see that it was a period of swift advance from the primitive rudeness that has been described. In the year 283 B. C. Etruria and her allies, hitherto perpetual foes to Rome, were totally defeated at the Vadimonian Lake, and about 265 B. C. Etruscan independence disappeared forever, simultaneously with the subjugation of all Italy. The whole peninsula her own, Rome reaches out beyond. The Græco-Egyptian monarchy, then at the very height of its power and magnificence under Ptolemy Philadelphus, seeks her alliance. The Greek cities across the Adriatic court her favor. She pushes her conquering arms across into Sicily, which, in 241 B. C., becomes a Roman province, followed a little later by Corsica and Sardinia. No longer *prima inter pares* among the warring tribes and nations of Italy, she has sprung as if at a single bound into her position as one of the great powers of the world.

The absorption of Magna-Græcia and Sicily brought under her dominion for the first time a cultured people and populous cities, filled with and habituated to Grecian art and the appliances of refinement and luxury, and the sun-dial of Catina is but one instance of what was borne away to embellish the Imperial City. Doubtless the fame and wealth of the capital offered strong inducements to the skilled artisans of dismantled Tarentum, while the captives of Agrigentum may, in their turn, have contributed in no small degree to her industrial population.

The colonists planted by thousands far and wide over the conquered territory of Italy formed a sturdy rural population—a strong reliance in peace and war. And the great highways built for the march of the legions, and hitherto scarcely resounding but to their armed tread, now became the arteries of a steady and growing traffic. The needs of a circulating medium in her domestic and foreign trade were ill supplied by the copper coins she had struck hitherto and the products of various foreign mints that had come to her with her other acquisitions, and, in 258 B. C., she began to coin silver of her own. Carthagenian jealousy of her aggressive rivalry led to the necessity of maintaining a fleet, and, after some disasters, to maritime supremacy.

"The ten years preceding the first Punic war," says Dr. Thomas Arnold, "were probably a time of the greatest physical prosperity which the mass of the Roman people had ever seen," and it is in this very decade, with enlarging industries, with a growing commerce, with multiplying complications in public and private busi-

ness, that Rome stepped from the spring time of her history into her vigorous summer, and with this step time-keeping began.

The Catanian sun-dial was no mere gnomon such as had been introduced into Greece three centuries earlier: Greek science and genius had been at work on it, and it was an improved instrument, constructed for a particular latitude, and that 5° south of Rome. But there was no science yet in Rome to detect its imperfections, and, in spite of them, for ninety-nine years it served as the regulator of time for the city. Scarcely credible as it may seem, it was not, therefore, till about a century and a half before the Christian era that Rome possessed her first accurate time-keeper in the form of a sun-dial constructed especially for her own latitude, which was set up at the instance of the Censor Marcius Phillippus. Meanwhile dials of imperfect construction had become common in the city; so common, indeed, that, as new inventions nowadays afford material for the American paragrapher, they became the happy source of quips and epigrams. Thus Plautus, in what I admit is rather a liberal version:

> When I was young, no time-piece Rome supplied,
> But every fellow had his own—inside;
> A trusty horologe, that—rain or shine—
> Ne'er failed to warn him of the hour—to dine.
> *Then* sturdy Romans sauntered through the Forum,
> Fat, hale, content; for trouble ne'er came o'er them.
> But *now* these cursed dials show their faces,
> All over Rome, in streets and public places;
> And men, to know the hour, the cold stone question,
> That has no heart, no stomach, no digestion.
> They watch the creeping shadows—daily thinner—
> Shadows themselves, impatient for their dinner.
> Give me the good old time-piece, if you please,
> Confound the villain that invented these!

As formerly, in Greece, the clepsydra came to supply the deficiencies of the sun-dial, so history repeated itself in Rome. Pliny ascribes its introduction to Scipio Nasica in the year of Rome 595 (158 B. C.). Of the form of this clepsydra we have no knowledge, but it was no longer a mere time-check, such as was used in the Athenian courts, but a true time-keeper, capable of indicating continuously the hours both of day and night. There were many adopted for this purpose, as will presently be shown. In Pompey's third consulship (52 B. C.), he introduced the custom of apportioning the

time of orators in the courts by the clepsydra, after the Greek fashion. The decline of Roman oratory has been attributed to this restriction, which, after all, seems to have left the speaker a fair amount of time. Pliny says: "I spoke for almost five hours, for to the twelve clepsydræ of the largest size which I received, four were added." Some read *twenty* in place of *twelve*, which seems to be the preferable reading, and out of it we get some idea of the time consumed by one discharge of the vessel. If twenty-four clepsydræ is "almost five hours," it appears likely that the discharge was at the rate of five to the hour; and this helps us to better understand Martial's epigram to a tedious lawyer who had been permitted to exhaust the clepsydra seven times. It makes something less than an hour and a half; but the orator's mouth was as dry as his discourse, and he drank copiously, whereupon the witty poet suggests that he can satisfy his thirst and his audience at once by drinking out of the clepsydra.

In Rome at this period the use of the clepsydra, in the form both of a time-check and time-keeper, was quite general—not as the house-clock is common to-day—but generally known and serving to regulate the hours of business and pleasure. Men of means had them in their houses, and slaves were kept whose special duties were to watch them and report the hour. Idlers meeting in the market place or forum accosted each other with "*Hora quota est*," by way of opening conversation, as they now comment on the weather or compare watches. Generals took the water-clock with them to the field and relieved the watch by it during the hours of night. An allusion by Cæsar has been the source of a curious misconception, that he found this instrument in use among the Britons at the time of his invasion. Evidently referring to the phenomenon now so familiar of the Arctic night he says some had reported that at Mona the night at the winter solstice lasted for a month. "Our inquiries," he continues, "did not confirm this, but by careful measurements *ex aqua* we saw that the nights were shorter than on the continent." To draw from this the conclusion that the early Britons had water-clocks is about as if we were to infer from the Signal Service observations at Point Barrow that the Eskimos of that region were found in possession of the thermometer.

Greece, too, had by this time fallen under Roman rule, and the clepsydra as a time-keeper was well-known in Athens. The most eminent instance of it, probably, for all time, was in the Tower of the

Winds, which, fifty years before our era, was erected in the market place in that city. A running stream kept at a constant level the water in an upper vessel, the discharge from which raised a float in a lower one, like that in the Chinese water-clock before described. This was the public time-piece of Athens, and its indications could always be compared with those of the sun-dials on the frieze of the octagonal building by which it was enclosed. At the top of the roof was a weather-vane in the form of a Triton, who pointed with his trident towards the prevailing wind. This institution served for Athens the combined purpose of a Naval Observatory and a Weather Bureau.

With time-keeping so generally observed, and with a fair degree of accuracy secured by means of mechanical contrivances, this history closes, but in reciting it I have omitted or only incidentally touched upon the growth of the idea of dividing the day into hours and the mechanical elaboration of what, in its perfected form, is properly termed the water-clock. These elements, in the complete history, are too important to be omitted.

Since we are only concerning ourselves with time-keeping in common life, we need not go back to Egypt or Babylon, where there is no evidence that it was known except to the initiated few. Whatever ideas are conveyed to us by the twelve divisions of the day known to the Babylonians, or by the graduated dial set up by the Hebrew king in his palace, it is evident that if the Greek philosophers derived from their Eastern contemporaries any notions of common or domestic time-keeping, these failed to take root in their soil until Greece, by her own progress, had prepared it to receive them.

The divisions of the day known to Homer were three: ἠώς, for the period from sunrise till noon; μέσον ἦμαρ, for mid-day; and δείλη, for afternoon till sunset. These divisions were employed in Greece to the latest period and long after others more exact were in use. Even with our nice observance of time we have similar general expressions for parts of the day, such as morning, mid-day, afternoon, and many others often having only local use.

If the Babylonian "twelve parts" of the day were made known to the Greeks, as Herodotus tells us, it was a knowledge for which they had no use at that period. With the introduction of the gnomon they began to observe time more closely, but they had no names for its arbitrary divisions.

When the shadow was six feet long it was time to bathe; when twice that length it was time to sup. It is not even certain, to my mind, that they clearly appreciated the varying length of the day. There is no possibility of setting a summer and winter day side by side and comparing them, and the difference between them can only be determined by some means of measuring time quite distinct from observation of the sun or shadows. The great difference between the days of winter and summer in our latitude, which is nearly that of Athens, seems to us to be plainly discernable; but if we could divest ourselves of our acquired knowledge and of our means for keeping time, and put ourselves in the place of the Greek of 600 B. C., we should probably fail to observe the fact except very dimly.

Accurate division begins with the observation of noon, and we have seen pretty clearly when this began in Greece. The next step in subdivision consists in dividing the day into quarters by dividing equally the periods before and after noon. This division was at least known to the Greeks, but I see no evidence that it was in common use; nor, in fact, does it appear that they, in daily life, made use of close subdivisions until Roman influences prevailed and the Roman divisions of the day were adopted.

In Rome the division of both the day and night into four watches resulted naturally from the military character of her people and remained in use down to the latest period. These divisions of the day corresponded with what were afterwards the third, sixth, and ninth hours, and it was customary for one of the subordinate officers of the praetor to proclaim them. They had also a three-part division corresponding to that of the Greeks.

Artificial means of measuring time came to the Romans so much later than to the Greeks that great improvements had been wrought in them. Science had gone so far in Egypt and Sicily that sun-dials were constructed for particular latitudes; but it is not clear that, as at first introduced, they were graduated. The same subdivision of the day into four watches that has just been noticed might obviously give the first suggestion of such graduation by bisecting the angle between the noon-mark and those of sunrise and sunset. As a closer subdivision was required the Romans appear to have taken one already known in Egypt and better adapted to the latitude of Thebes and Memphis than to that of Italy. This was the division of the day and night into twelfths (which varied in their length as

the seasons changed) and is commonly known as the Roman system. Before intimate relations began between Rome and Egypt, Greece had already been annexed and the same system was introduced there, as also in Palestine and wherever the Roman eagles penetrated. This division adapted itself perfectly to the older one already in use in Rome and its adoption was natural. The only change in the sun-dial that it involved was a further subdivision of the spacing. Being an improvement that cost nothing and could be adopted without any radical changes in the habits of daily life it was one to commend itself to a people who were slow to change; and when, a few years later, in the middle of the second century B. C., Hipparchus proposed the division into equinoctial hours, the same as used now, the proposition met no welcome. This accurate and convenient system did not adapt itself to the established notions of the times, and the Roman hours secured a firmer and firmer grip, resulting, as I am inclined to believe, in one of the most remarkable instances of retardation of invention that history records. It was not until Europe had emancipated herself from slavery to this most awkward of time systems that modern time-keeping became possible. For many centuries invention was, as it were, thrown off the scent by the necessity of converting the regular and uniform motions which could be given to mechanism into means for displaying the ever-varying hours of the Roman system.

The word "hora," proposed by Hipparchus to express these divisions of the day, was adopted in its new sense by Greeks and Romans simultaneously and has ever since held its place in all the languages of Europe. In fact it was used in two senses: in its significance of the varying Roman hour it could not be employed to define exact intervals of time; when employed for that purpose it expressed exactly what we express by it now—the twenty-fourth part of a civil day. The passage in Pliny I have quoted is not intelligible unless the word "hour" is employed in this sense.

Enough was said in the early part of this paper to show the line in which the clepsydra developed, the water clock at Canton and that in the Tower of the Winds at Athens being examples of it in a fairly perfected state as a time-keeper. Invention had succeeded in giving to the rising pointer a regular motion and adapting it well to its purpose. Other advances were made in it, and of these it remains to speak. Improvement, handicapped by the clumsy Roman hours, found in this fact a stimulus to ingenuity. To adapt it to indicate

these hours one rude scheme was to reduce the capacity of the vessel from which the water flowed by coating it with wax in the winter time. The orifice remaining unchanged it emptied more quickly. The wax was gradually removed as the days lengthened. Of course, the same instrument could not serve for both day and night. Less clumsy means for regulating the flow, as by adjusting the size of the orifice, were afterwards invented. One of these involved the passage of the water through a hollow cone or funnel, in which was an interior cone capable of adjustment for each day in the year; another, invented by Ctesibius, left the water flow, and consequently the rise and fall of the float, constant, but included an automatic device by which the graduated scale over which the marker traveled was changed daily.

This difficulty in adapting the clepsydra to keep Roman time is precisely the same that the early Dutch navigators met with on their introduction of the clock into Japan, where the division of the day is into ten hours of varying length. The plan they adopted is a clumsy one, but of the same character as that of Ctesibius, since they did not attempt to alter the rate of the clock, but attached movable indications to the dial so that they might be changed with the season. One of these clocks is in the possession of the Bureau of Education, a gift from the Japanese Government after the Centennial Exposition of 1876.

But improvements in the clepsydra such as have been described, notwithstanding the ingenuity and mechanical skill they displayed, are of little consequence to us, since they were not towards the accomplishment of the final result but away from it. The actual steps towards the modern clock appear to be these: First, the employment of the ordinary rack and pinion device. If we are right in attributing the invention of gear-wheels to Archimedes, this application could not have been made earlier than the middle of the third century B. C. (287 to 212). It is attributed to Ctesibius, who, for many reasons, as I have said already, is placed a century later than this. A series of teeth, commonly called a rack, was attached to the side of the rod, which was supported by the float, and had heretofore served only as an index. Fixed on a horizontal shaft above the vessel was a small toothed wheel, with which the toothed rack engaged, and which was, therefore, caused to turn by the rise of the float. On this shaft was a pointer attached like the hour-hand of a clock and traveling over a similar dial. To make

this hand complete a circuit in 12 or 24 hours is, obviously, only a question of the proportion of parts. The next step forward dispensed with the rack and pinion and really was in the line of greater simplicity. In place of the toothed wheel a grooved pully was used, over which passed a cord from the float, being kept tight by a weight at the other end. The hand remained on the wheel shaft as before, and with the gradual rise of the float, traversed the dial.

We have reached the point where we may say "*presto, change,*" and behold, a clock springs into view, for it is instantly apparent that with this structure it is no longer the water that advances the hand; water is not the motor now. The weight is the motor, and its fall is retarded by the float, which only permits its descent as fast as the rise of water in the vessel permits its own rise. We have an actual weight clock, with what we must be content to regard as a water escapement; it is far enough from our perfected timepiece, but in respect to its essential elements it differs in but one, and henceforth the problem of the clock is only that of escapements. But we need not expect it to be solved at once. It will be centuries before the actual problem will be recognized, so great is the obscurity with which the Roman time system has beclouded the subject.

There is a long and mournful perspective before us. The golden age of Roman literature is here, but she has yet to see the greatest extent of her empire and the summit of her own magnificence. A long line of Cæsars will come, base and noble alternating. Her decline will follow her glory; her palaces are to be plundered by barbarous northern invaders; her empire is to be shattered; out of her vast domain new peoples and nations and empires scarcely less mighty than her own are to spring, while she herself sinks to the paltry dimensions of a village. Her polished speech shall die from men's lips, but the rude dialects of her provinces, mingling with the uncouth tongues of illiterate Franks and Goths, shall develop into new languages, in time to become as perfect vehicles of thought as their original. New forms of government and of social order shall spring from her laws and institutions and philosophies; and from the hills of credulous and despised Judea is to burst a new religion, before whose bright beams the perpetual fires of Vesta shall pale and the whole train of Olympian gods vanish like the mist. But amongst these unconceived changes, and through the storms that shall sweep away and the cataclysms that shall engulf all the objects

of her pride and glory and reverence, there shall still endure what she cared least for—constant in all their inconstancy—the Roman hours.

The problem of improving the time-keeper is one with which cloistered scholars and mechanicians will not cease to contend, but the barrier that Rome has set up will continue to baffle their ingenuity; and when thirteen centuries shall have passed since Hipparchus in vain urged the advantages of the equinoctial system and Ctesibius strove to solve the riddle of Roman time by some practical mechanism, we shall still find *Bernardo Monachus* recording how the monks of Cluny perplexed their pious souls with the old, old question, and how the good sacristan must needs go out into the night to learn—from the stars—if it were time to call the brethren to prayer.

DISCUSSION.

The above paper, read before the Anthropological Society of Washington April 5, 1887, was discussed by Messrs. PIERCE, MASON, THOMPSON, BLISS, BLODGETT, MALLERY, and BABCOCK.

Prof. MASON referred to a simple time-check used by a Chinese physician. It was a joss-stick broken so as to have several angles. The doctor set fire to one end and instructed his patient to take his first dose when the fire reached the first angle, another when it reached the second, and so on.

Mr. A. H. THOMPSON spoke of a rude timepiece which he had seen among the Zuñis. It was a plate set in the wall of a hut opposite a hole in the other wall. When the sunlight coming through the hole fell upon the plate the Zuñis knew that it was time to plant corn.

Mr. DORSEY referred to the divisions of time from sunrise to sunrise observed among certain Indians in Oregon. These Indians have about forty names for different parts of the day and night.

Mr. BLODGETT, referring to the speaker's doubt whether the Romans appreciated the difference in the length of the days at different seasons of the year, remarked that it is an old saying that time is measured by events. While small variations in the length of the day might not be detected, it is hardly conceivable that any people who had sufficient advancement to have occasion to pass over the same areas in different seasons should not observe that

such an act as going to a distance for fuel or for water could not be repeated so many times in the short days as in the long ones. Any action whose rate became somewhat habitual, as the movement of an army, the carriage of burdens, or the performance of agricultural tasks, would form a basis of comparison that would be forced on the attention of the actors. When beasts of burden were used their movements would emphasize the difference between the long and the short days. Even in our day time in Oriental countries is measured by the gait of the camel.

Col. MALLERY remarked that the marching of armies and the hauling of produce do not ordinarily take place in the winter season.

Mr. BABCOCK said that hunting was pursued at all seasons. The Indians who lived here used to go over to the Patuxent river to hunt and fish at all times of the year. It is hardly conceivable that they did not observe how much longer they could travel before dark in summer than in winter.

CURIOUS VARIETY OF BLOOD REVENGE.—British Consul Plumacher reports the following type of vendetta among the Goajira Indians living on the extreme northwestern part of Venezuela. By the payment of the compensation of "tears and blood" any injury may be condoned—not the aggrieved one, but his relatives, especially those on the mother's side, demanding the blood money. If an Indian accidentally injure himself, his mother's family immediately demand of him the "payment of blood," on the theory that as his blood is also their own he has no right to shed it without compensation. The relatives of the father claim the payment of "tears," which is not so large. Even the friends who witnessed the accident are entitled to pay for their grief. The amount of payment depends on the injury. A trifling cut of the finger calls for a little corn or something of equal value; a more serious grief is assuaged with a sheep or a cow. If the injured party is too poor he must beg from hut to hut, and no one will refuse to contribute. If an Indian borrows a horse from a friend and is thrown or injured the owner must pay, since the accident would not have happened if he had not lent the animal. If a man is injured by his own animal he himself must compensate his relatives. The seller of an article is responsible for the results of its misuse. If a person should be wounded or lose his life in attempting to kill another the latter must pay blood and tear money in the same manner as if he had been the aggressor. Should a child die in the absence of one of its parents the absent one may demand from the other payment for the tears supposed to be shed over the occurrence.—Jour. Soc. Arts, xxxv, 928.